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Special Report
Geophysical Activity in 1980

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INTRODUCTION

Statistical data on geophysical activity in 1980 are gathered from two survey questionnaires mailed to more than 500 companies, contractors, government agencies, and institutions throughout the free world. One questionnaire was the original form which was designed primarily for reporting petroleum activities, and the other, an alternate form, was designed to facilitate reporting of nonpetroleum geophysical activities. We have attempted to gather data from all users of geophysical techniques in the areas of petroleum, mining, geothermal, and groundwater exploration and from those who employ geophysical methods in engineering, oceanography, and research. In general, response to the survey was good. However, we feel that there are new users of geophysical methods we are not reaching. If you did *not* receive our 1980 questionnaires, please let me know so we can include you on our mailing list for 1981. (As always, data submitted by individual organizations are held strictly confidential.)

Detailed information was gathered on airborne, drill hole, land, and marine geophysical surveys. Statistics were compiled on miles of coverage, number of stations, drill-hole footage, time spent in crew-months or man-months, and acquisition costs. Data not supplied on the questionnaires by the respondent were estimated on the basis of massive statistical averaging for the area and techniques reported. This process is necessary to avoid distortion of individual statistical items.

This report, when compared to past annual reports, provides a basis for detecting and analyzing trends in technological developments and exploratory trends in geographical areas. Changes in these trends reflect the influence of many factors, such as technological advances, inflation, government regulations, and exploration philosophy. Cost figures are sensitive to many factors, such as operational environment, length and nature of the survey, type of instrumentation, etc. Unit costs reported by universities are substantially lower than those reported by industry due to the use of student labor and donated equipment. These costs, however, must be averaged with industry costs to accommodate the format of the report. Therefore, when examining unit cost figures, one must be cognizant of the broad spectrum of activity embraced by individual categories.

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Report of the SEG Geophysical Activity Committee. The members of the Committee are W. E. Blakely, Antonio Desa, T. L. Dobecki, H. R. Espey, Lin Evans, D. A. Fahlquist, A. F. Gangi, R. R. Hartman, D. A. Hastings, F. W. Hinrichs, R. J. Jones, F. P. Kronberger, J. R. McBeth, R. S. Middleton, G. E. Montgomery, J. Roth, T. R. Salisbury, R. J. Senti, Chairman, Betty Stone, and Wayne Suyenaga.

Table 1. Total world-wide expenditures in US$ (thousands) by survey type and objective.

Type	Petroleum[1]	Minerals	Engineering	Geothermal	Groundwater	Oceanography	Research	Total
Land	2,046,771	23,035	3,610	4,116	4,111		5,433	2,087,076
Marine	841,234		10,472			5,299	4,040	861,045
Airborne	18,196	27,369	301	309	93	240	376	46,884
Drill hole	838	3,283	628	1,903	262		345	7,259
Total	2,907,039	53,687	15,011	6,328	4,466	5,539	10,194	3,002,264

[1]Includes processing and interpretation costs for land and marine. See text for details.

Note: All tables in this report where figures are expressed in thousands of dollars have been rounded off as individual items; but the computer keeps track of the truncated numbers and then the sums of the individual items are rounded off. As a result of this procedure, the rounded individual items may not add up precisely to the rounded sums.

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Table 2. Total worldwide expenditures in US$ (thousands) by area and survey objective.

Area	Petroleum[1]	Minerals	Engineering	Geothermal	Groundwater	Oceanography	Research	Total
International	24,568					138	3,470	28,176
U.S.A.	1,300,313	8,341	9,238	3,541	696	1,136	5,013	1,328,278
Canada	313,726	15,164	403	707		1,072	171	331,243
Mexico	71,489	442	1,000	80				73,011
So. America	235,384	656	170		116	2,252	115	238,693
Europe	256,990	12,287	2,537	700	180	326	290	273,310
Africa	292,294	9,012	503	1,300	3,472	375	110	307,066
Middle East	151,546	438	250					152,234
Far East	203,797	809	756			240	1,025	206,627
Australia/ New Zealand	56,932	6,538	154		2			63,626
Total	2,907,039	53,687	15,011	6,328	4,466	5,539	10,194	3,002,264

[1]Includes processing and interpretation costs.

1980 HIGHLIGHTS

Record inflation along with the growing worldwide scarcity of petroleum and of many minerals brought a sharp increase in geophysical expenditures in 1980. Worldwide expenditures for geophysical exploration were up 46 percent, rising above the US$3 billion mark (see Table 1). This is the largest one-year increase ever recorded. The increase came primarily in the petroleum area, up 49 percent. Expenditures reported for mining, geothermal, and research were up 21, 29, and 71 percent, respectively, while reports of money spent on groundwater, engineering, and oceanography were down 17, 32, and 77 percent, respectively. The large drop in oceanography expenditures is due to a shortage of funds for university and government oceanographic surveys. The decline in groundwater and engineering activity is believed due to incomplete information. This under-reported condition reflects the difficulty in getting reports from these segments of the industry.

Distribution of expenditures by geographic area and survey objective is shown in Table 2. Approximately 44 percent of all expenditures for geophysical work was spent in the United States. Geophysical expenditures in the U.S. increased 40 percent over 1979. Canada showed an increase of 22 percent, while

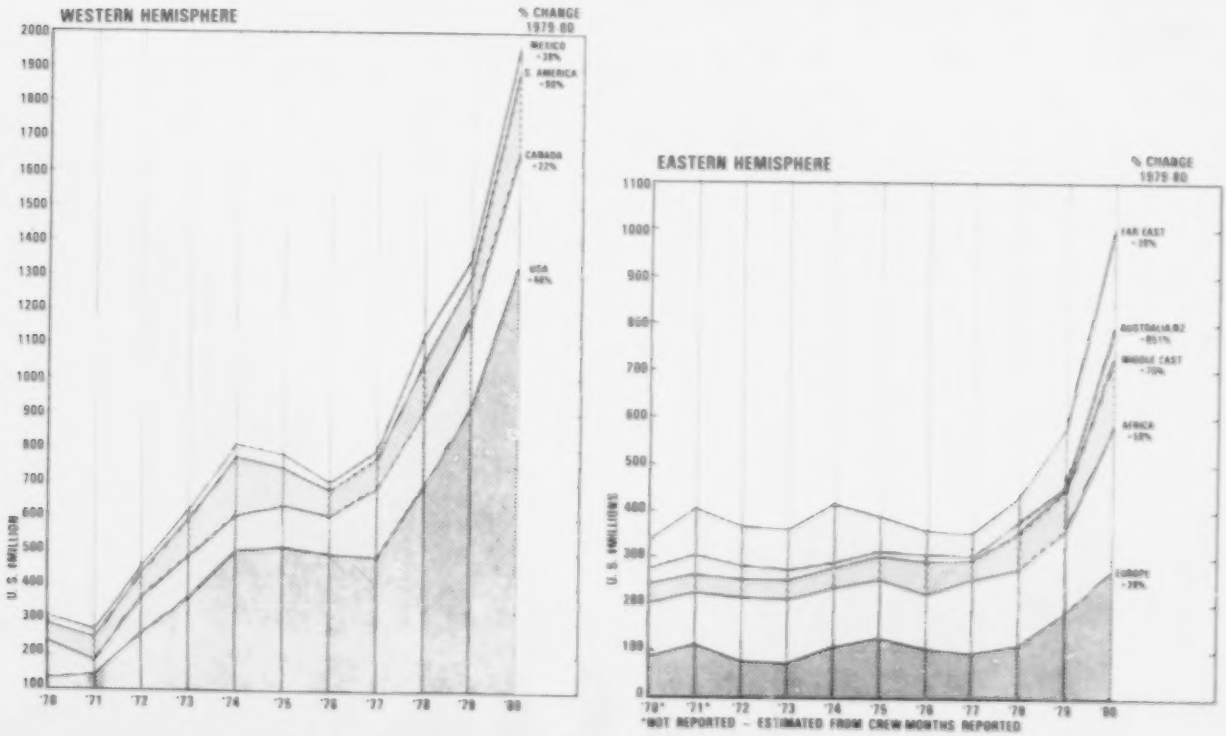

FIG. 1. Total expenditures on petroleum exploration, 1970-1980.

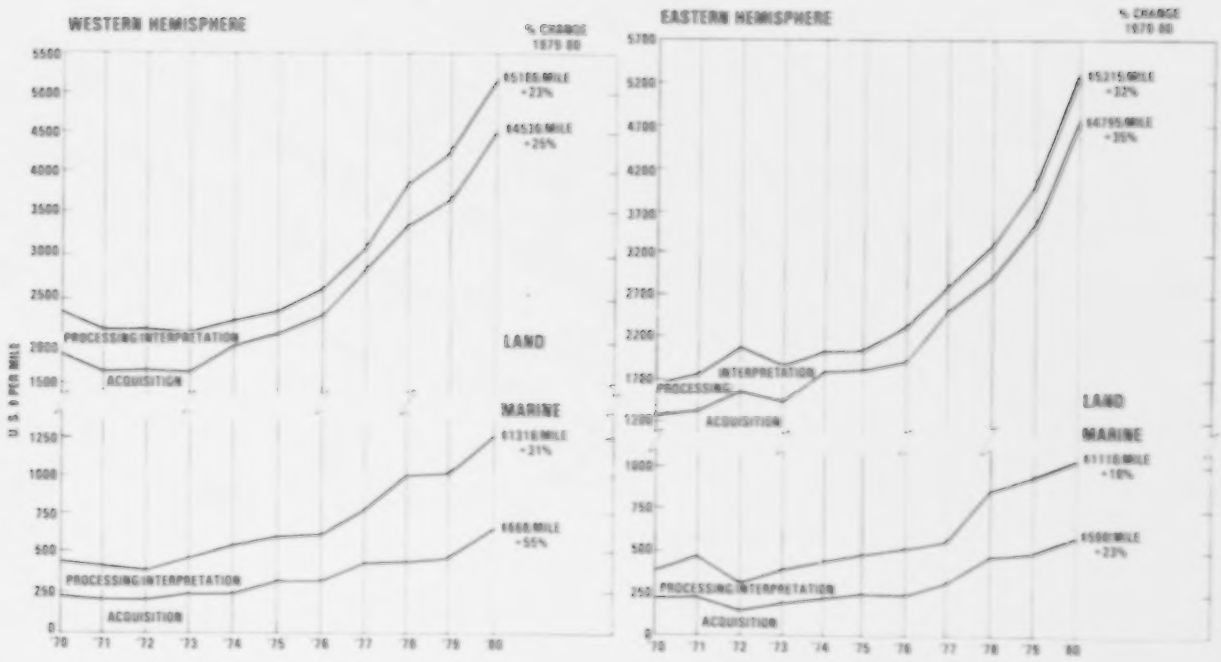

FIG. 2. Average cost per mile for petroleum surveys, 1970-1980.

Europe, Mexico, and the Far East all saw a 39 percent increase in activity. Africa, the Middle East, and South America had increases of 59, 70, and 90 percent, respectively, while Australia/New Zealand enjoyed the largest increase in activity of 651 percent. This large increase might reflect an under-reported condition in prior years.

The costs of processing and interpretation are included in Tables 1 and 2 and Figures 1 and 2, but all other tables show acquisition costs only. Since we do not receive information on processing and interpretation costs, these figures must be estimated. US$650 per line-mile was used for the Western Hemisphere and US$520 per line-mile was used for the Eastern Hemisphere. The higher cost in the Western Hemisphere is based on the premise that, in general, a more rigorous processing and interpretation treatment is required because of the subtle structural and stratigraphic prospects that may be economically viable objectives in much of the Western Hemisphere but are not usually primary targets in much of the Eastern Hemisphere. These cost estimates were increased over 1979 because of the effects of inflation and the strong movements toward "seis-strat" exploration and the "people and processing" intensive nature of this technology.

Table 3. Worldwide petroleum land seismic activity.

Area	Acquisition costs (US $)	Line-miles	Crew-months* Company	Crew-months* Contract	Crew-months total*	Average miles/month	Average cost/month	Average cost/mile
U.S.A.	873,139,719	184,088	1,205.0	3,408.4	4,613.4	39	189,261	4,743
Canada	230,061,177	58,049	98.5	568.0	666.5	87	345,178	3,963
Mexico	28,850,000	6,415		95.0	95.0	67	303,684	4,497
So. America	115,281,572	26,445		427.7	427.7	61	269,538	4,359
Europe	120,029,290	25,713		444.1	444.1	57	270,275	4,668
Africa	202,372,472	44,858		534.1	534.1	83	378,903	4,511
Middle East	120,517,581	21,945	3.0	331.0	334.0	65	360,831	5,491
Far East	92,551,225	17,367	89.0	250.2	339.2	51	272,851	5,329
Australia/ New Zealand	23,621,731	6,721		62.6	62.6	107	377,343	3,514
Total	1,806,424,767	391,601	1,395.5	6,121.1	7,516.6	52	240,324	4,612

*Total includes government and university activity.

Table 4. Petroleum land seismic line-miles by energy source.

Area	Dynamite	Compressed air	Electrical	Gas exploder	Weight drop	Solid chemical	Vibrator	Other	Total Line-miles
U.S.A.	94,624	9,462	625	2,450		992	75,460	475	184,088
Canada	49,250	1,030					7,769		58,049
Mexico	720	600					2,525	2,570	6,415
So. America	8,921	180				340	17,004		26,445
Europe	18,911						6,547	255	25,713
Africa	28,479				4,318		12,061		44,858
Middle East	4,507				3,831		13,607		21,945
Far East	13,648						3,719		17,367
Australia/ New Zealand						244	6,375	102	6,721
Total	219,060	11,272	625	2,450	8,149	1,576	145,067	3,402	391,601

PETROLEUM EXPLORATION

Almost 97 percent of all geophysical dollars were spent on the search for petroleum. Over US$2.9 billion was spent on petroleum exploration in 1980. Expenditures in the U.S. increased 42 percent, while Canada increased 22 percent. South America showed a 91 percent increase, while Australia/New Zealand rose over 740 percent compared to 1979. Geophysical activity in the Western Hemisphere increased 42 percent while the Eastern Hemisphere increased 65 percent.

A 10-year history of geophysical activity in both the Western and Eastern Hemispheres is shown in Figure 1.

SEISMIC SURVEYS

The seismic method accounted for over 94 percent of all expenditures in geophysical activity. This statistic, plus the strong tendency for wildcatting to follow and parallel seismic activity, has caused those interested in forecasts of petroleum exploration to regard seismic activity as the barometer for exploration. A 10-year history of the cost of petroleum seismic surveys in both the Eastern and Western Hemisphere is shown in Figure 2. In the Western Hemisphere, acquisition costs per mile of land seismic surveys were up over 25 percent, while marine costs rose nearly 55 percent. In the Eastern Hemisphere, acquisition costs per mile for land seismic rose 35 percent, while marine costs rose almost 24 percent. These increases reflect the ever increasing cost of operating seismic crews.

The total number of miles of seismic data recorded worldwide was up 17 percent on land and 16 percent in marine work (see Tables 3 and 5). Group seismic surveys and speculation surveys became much more prevalent in 1980 as operators, reacting to increasing costs of gathering data, chose to sacrifice the competitive advantages of proprietary data for the low cost of nonproprietary data. As for energy sources, dynamite and Vibroseis accounted for 93 percent of all land seismic work, while air guns and gas exploders captured over 84 percent of the marine work (see Tables 4 and 6).

A more comprehensive breakdown of statistical data on petroleum surveys, sorted by geographic area, can be seen in Table 7. Table 8 shows petroleum seismic activity by states in the U.S. Some of the states showing large gains over last year were Alabama, Georgia, Maryland, Michigan, Montana, New York, Utah, and West Virginia. Tables 9 and 10 show petroleum seismic activity in Canada and Mexico, respectively. Canada experienced a 19 percent increase over 1979, while Mexico saw a 53 percent increase. This large increase in Mexico may be a result of under-reporting in prior years.

A 48-year history of seismic exploration in the U.S. is shown in Figure 5. This information is compiled by the SEG Business Office. Data for this graph are gathered monthly by telephone.

Table 5. Petroleum marine seismic activity.

Area	Acquisition costs (US $)	Line-miles	Crew-months* Company	Crew-months* Contract	Crew-months total*	Average miles/month	Average cost/month	Average cost/mile
International	24,568,192	45,038		60.1	60.1	749	408,788	545
U.S.A.	142,595,444	202,694	87.2	261.0	348.2	582	409,521	703
Canada	27,359,098	26,953	4.6	23.7	28.3	952	966,752	1,015
Mexico	14,679,000	32,335		30.0	30.0	1,078	489,300	454
So. America	42,662,842	78,030	5.1	86.9	92.0	848	463,726	546
Europe	60,102,804	96,479	3.2	121.8	125.0	771	480,822	622
Africa	29,861,440	58,225	3.3	150.3	153.6	379	194,410	512
Middle East	7,937,650	12,527		12.0	12.0	1,043	661,470	633
Far East	47,687,942	83,592	18.8	161.5	180.3	463	264,492	570
Australia/ New Zealand	18,031,369	22,601		17.8	17.8	1,269	1,012,998	797
Total	419,880,381	658,474	122.2	925.1	1,047.3	629	400,917	638

*Total includes government and university activity.

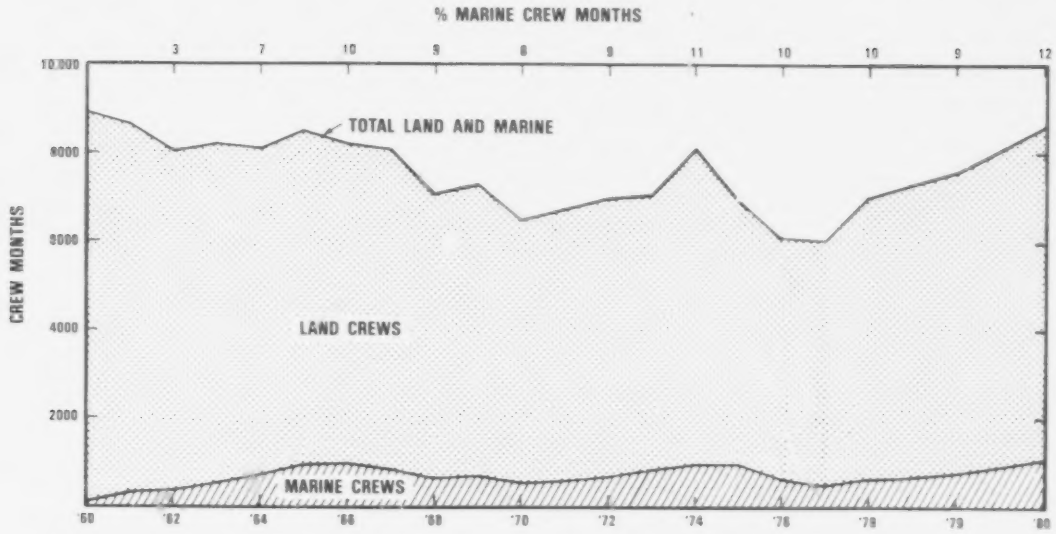

FIG. 3. Worldwide seismic activity in crew-months, 1960-1980.

Table 6. Petroleum marine seismic line-miles by energy source.

Area	Compressed air	Electrical	Gas exploder	Implosive	Solid chemical	Other	Total line-miles
International	31,486		5,400	7,552	600		45,038
U.S.A.	126,502	9,238	63,600	3,324		30	202,694
Canada	20,888		6,065				26,953
Mexico	32,335						32,335
So. America	53,605		6,425		18,000		78,030
Europe	55,872	700	13,975	21,432	4,500		96,479
Africa	28,697	1,080		23,198	5,250		58,225
Middle East	7,752			3,275	1,500		12,527
Far East	50,193	1,120	29,100	1,679	1,500		83,592
Australia/ New Zealand	22,601						22,601
Total	429,931	12,138	124,565	60,460	31,350	30	658,474

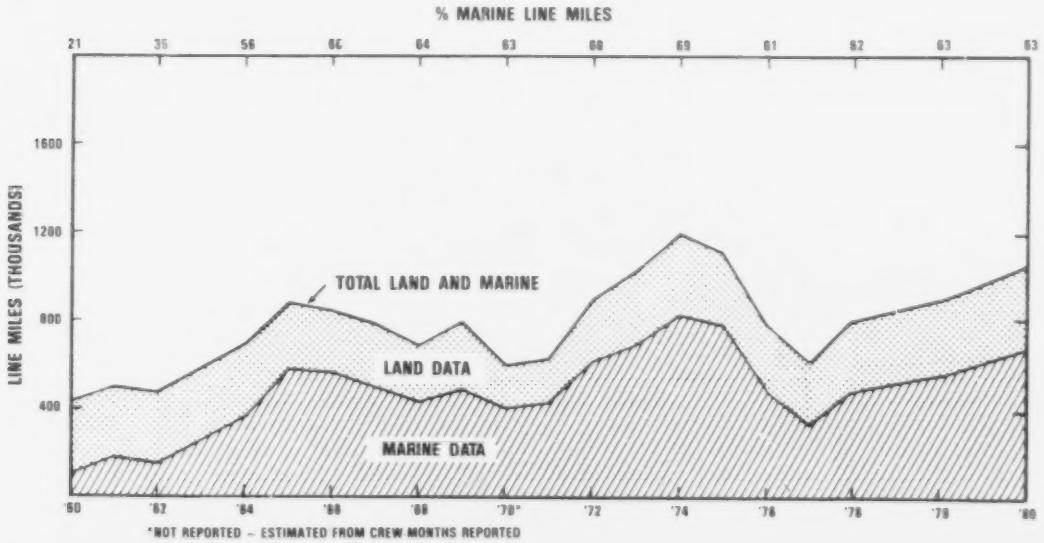
% MARINE LINE MILES
21 35 56 66 64 63 68 69 61 62 63 63
1600
1200
800
400
LINE MILES (THOUSANDS)
TOTAL LAND AND MARINE
LAND DATA
MARINE DATA
'60 '62 '64 '66 '68 '70* '72 '74 '76 '78 '79 '80
*NOT REPORTED – ESTIMATED FROM CREW MONTHS REPORTED

FIG. 4. Worldwide seismic activity in line-miles, 1960-1980.

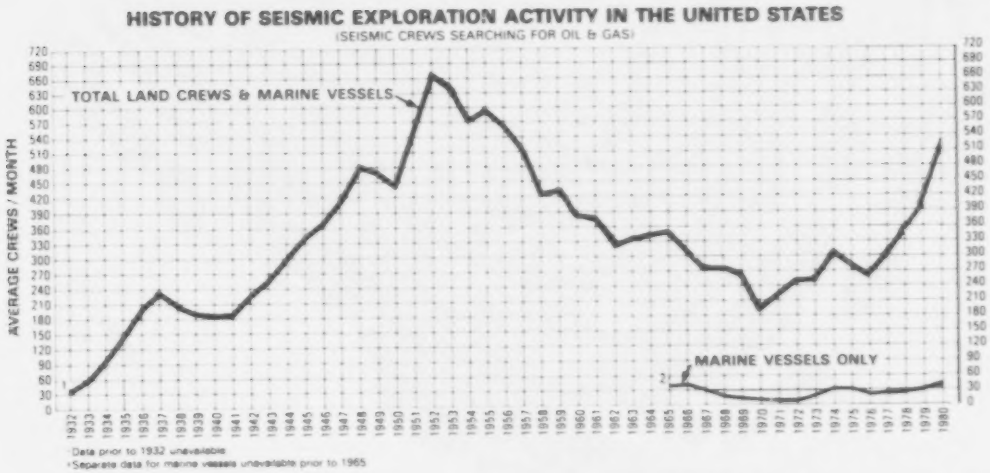
HISTORY OF SEISMIC EXPLORATION ACTIVITY IN THE UNITED STATES
(SEISMIC CREWS SEARCHING FOR OIL & GAS)
TOTAL LAND CREWS & MARINE VESSELS
MARINE VESSELS ONLY
AVERAGE CREWS / MONTH
Data prior to 1932 unavailable
*Separate data for marine vessels unavailable prior to 1965

FIG. 5. History of seismic exploration activity in the U.S., 1932-1980. The total crews working in a given year is not synonymous with the crew months worked that year.

Table 7. Worldwide average unit costs for petroleum surveys.

Area, survey type, and method	Crew-months total*	Line-miles	Acquisition costs (US $)	Average miles/month	Average cost/month	Average cost/mile
International						
Marine						
Seismic (P-wave)						
Compressed air	42.4	31,486	18,891,392	742	445,551	599
Gas exploder	9.0	5,400	3,240,000	600	360,000	600
Implosive	7.7	7,552	2,976,800	980	269,714	275
Solid chemical	1.0	600	360,000	600	360,000	600
U.S.A.						
Land						
Seismic (P-wave)						
Dynamite	2,642.5	86,851	505,699,785	32	191,371	5,822
Compressed air	149.0	9,462	26,005,623	63	174,534	2,748
Electrical	1.0	625	250,000	625	250,000	400
Gas exploder	59.0	2,450	7,768,901	41	131,676	3,170
Solid chemical	36.3	992	5,934,507	27	163,485	5,982
Vibratory	1,439.0	71,895	276,279,255	49	191,993	3,842
Other	20.4	475	1,968,330	23	96,486	4,143
Seismic (S-wave)						
Dynamite	68.0	2,535	7,371,219	37	108,400	2,907
Vibratory	34.5	917	7,830,099	26	226,959	8,538
Seismic (refraction)						
Dynamite	89.0	5,238	22,002,000	58	247,213	4,200
Vibratory	76.0	2,648	12,030,000	34	158,289	4,543
Gravity	177.8	33,276	5,427,475	187	30,525	163
Resistivity	1.3	10	15,000	7	11,538	1,500
Electromagnetic	0.5	3	35,000	6	70,000	11,666
Induced polarization	28.0	2,235	1,060,000	80	37,857	475
Magnetotelluric	35.0	405	4,280,000	12	122,285	10,568
Marine						
Seismic (P-wave)						
Compressed air	238.0	126,502	99,476,180	531	417,967	786
Electrical	4.5	4,038	1,730,000	897	384,444	428
Gas exploder	91.2	63,600	36,794,264	697	403,445	578
Implosive	2.5	3,324	1,295,000	1,329	518,000	389
Other	1.0	30	100,000	30	100,000	3,333
Gravity	17.0	27,500	11,437,500	1,617	672,794	415

*Total includes government and university activity.

Table 7. Worldwide average unit costs for petroleum surveys (cont.)

Area, survey type, and method	Crew-months total*	Line-miles	Acquisition costs (US $)	Average miles/month	Average cost/month	Average cost/mile
USA (cont.)						
Airborne						
Magnetic	41.2	214,625	6,003,425	5,209	145,714	27
R-S side-scan radar	1.5	295,270	4,380,000	196,846	2,920,000	14
Drill hole						
Magnetic	3.0	**	22,000	**	7,333	**
Resistivity	3.0	**	22,000	**	7,333	**
Induced polarization	3.0	**	22,000	**	7,333	**
Canada						
Land						
Seismic (P-wave)						
Dynamite	541.0	48,900	201,879,905	90	373,160	4,128
Compressed air	2.0	1,030	582,000	515	291,000	565
Vibratory	113.5	7,769	25,849,272	68	227,746	3,327
Seismic (refraction) dynamite	10.0	350	1,750,000	35	175,000	5,000
Magnetic	30.0	600	360,000	20	12,000	600
Combined EM/Mag.	20.0	200	85,000	10	4,250	425
Induced polarization	4.0	240	200,000	60	50,000	833
Marine						
Seismic (P-wave)						
Compressed air	20.5	20,888	23,910,000	1,018	1,166,341	1,144
Gas exploder	7.8	6,065	3,449,098	777	442,192	568
Gravity	4.5	4,028	270,000	895	60,000	67
Magnetic	2.5	1,928	50,000	771	20,000	25
Airborne						
Magnetic	0.5	2,000	90,000	4,000	180,000	45
Mexico						
Land						
Seismic (P-wave)						
Dynamite	24.0	720	6,000,000	30	250,000	8,333
Compressed air	12.0	600	2,050,000	50	170,833	3,416
Vibratory	48.0	2,525	9,800,000	52	204,166	3,881
Other	11.0	2,570	11,000,000	233	1,000,000	4,280
Other	8.0	250	1,200,000	31	150,000	4,800
Marine						
Seismic (P-wave)						
Compressed air	30.0	32,335	14,679,000	1,078	489,300	454
Airborne						
Magnetic	9.5	43,500	1,573,000	4,578	165,578	36
So. America						
Land						
Seismic (P-wave)						
Dynamite	197.7	8,921	59,003,610	45	298,450	6,614
Compressed air	3.0	180	800,000	60	266,666	4,444
Solid chemical	10.0	340	1,275,000	34	127,500	3,750
Vibratory	217.0	17,004	54,202,962	78	249,783	3,187
Marine						
Seismic (P-wave)						
Compressed air	56.5	53,605	28,925,788	948	511,960	539
Gas exploder	11.5	6,425	6,537,054	558	568,439	1,017
Solid chemical	24.0	18,000	7,200,000	750	300,000	400
Gravity	13.0	16,050	9,515,300	1,234	731,946	592
Magnetic	1.0	1,050	15,300	1,050	15,300	14

*Total includes government and university activity. **Not applicable.

Table 7. Worldwide average unit costs for petroleum surveys (cont.)

Area, survey type, and method	Crew-months total*	Line-miles	Acquisition costs (US $)	Average miles/month	Average cost/month	Average cost/mile
Europe						
Land						
Seismic (P-wave)						
Dynamite	299.5	18,911	86,270,478	63	288,048	4,561
Vibratory	132.9	6,547	32,688,982	49	245,966	4,992
Other	11.7	255	1,069,830	21	91,438	4,195
Gravity	8.1	2,028	304,250	250	37,561	150
Marine						
Seismic (P-wave)						
Compressed air	78.0	55,872	41,190,639	716	528,085	737
Electrical	1.0	700	413,000	700	413,000	590
Gas exploder	17.7	13,975	9,054,640	789	511,561	647
Implosive	22.3	21,432	6,744,525	961	302,445	314
Solid chemical	6.0	4,500	2,700,000	750	450,000	600
Gravity	20.0	26,000	11,975,000	1,300	598,750	460
Airborne						
Magnetic	4.8	37,845	727,605	7,884	151,584	19
Drill Hole						
Sonic/vel. logging	16.0	**	312,480	**	19,530	**
Africa						
Land						
Seismic (P-wave)						
Dynamite	445.6	28,479	154,828,314	63	347,460	5,436
Weight drop	61.0	4,318	10,588,500	70	173,581	2,452
Vibratory	110.5	12,061	36,955,658	109	334,440	3,064
Gravity	8.0	7,382	1,887,989	922	235,998	255
Marine						
Seismic (P-wave)						
Compressed air	27.3	28,697	20,354,215	1,051	745,575	709
Electrical	1.2	1,080	300,000	900	250,000	277
Implosive	118.1	23,198	6,057,225	196	51,288	261
Solid chemical	7.0	5,250	3,150,000	750	450,000	600
Gravity	6.2	10,545	2,453,700	1,700	395,758	232
Magnetic	2.5	4,226	46,200	1,690	18,480	10
Airborne						
Magnetic	14.0	114,387	2,069,500	8,170	147,821	18
Middle East						
Land						
Seismic (P-wave)						
Dynamite	79.3	4,507	28,016,747	56	353,300	6,216
Weight drop	12.0	1,306	4,051,285	108	337,607	3,102
Vibratory	217.7	13,607	81,109,549	62	372,574	5,960
Seismic (S-wave)						
Weight drop	25.0	2,525	7,340,000	101	293,600	2,906
Magnetic	7.5	375	229,000	50	30,533	610
Marine						
Seismic (P-wave)						
Compressed air	6.6	7,752	6,136,900	1,174	929,833	791
Implosive	3.4	3,275	900,750	963	264,926	275
Solid chemical	2.0	1,500	900,000	750	450,000	600
Gravity	4.0	4,000	3,150,000	1,000	787,500	787
Airborne						
Magnetic	4.0	44,000	1,303,000	11,000	325,750	29
Drill hole						
Self-potential	12.0	**	480,000	**	40,000	**

*Total includes government and university activity. **Not applicable.

Table 7. Worldwide average unit costs for petroleum surveys (cont.)

Area, survey type, and method	Crew-months total*	Line-miles	Acquisition costs (US $)	Average miles/month	Average cost/month	Average cost/mile
Far East						
Land						
Seismic (P-wave)						
Dynamite	290.2	13,648	74,166,097	47	255,568	5,434
Vibratory	49.0	3,719	18,385,128	75	375,206	4,943
Gravity	2.5	500	40,000	200	16,000	80
Marine						
Seismic (P-wave)						
Compressed air	50.1	50,193	30,121,253	1,001	601,222	600
Electrical	1.0	1,120	150,000	1,120	150,000	133
Gas exploder	32.8	29,100	16,053,964	887	489,450	551
Implosive	94.4	1,679	462,725	17	4,901	275
Solid chemical	2.0	1,500	900,000	750	450,000	600
Gravity	15.0	33,733	8,873,750	2,248	591,583	263
Magnetic	4.0	5,120	118,131	1,280	29,532	23
Airborne						
Magnetic	7.1	46,031	1,044,480	6,483	147,109	22
R-S side-scan radar	1.6	15,000	983,000	9,375	614,375	65
Australia/New Zealand						
Land						
Seismic (P-wave)						
Solid chemical	3.0	244	2,831,693	81	943,897	11,605
Vibratory	55.0	6,375	20,310,138	115	369,275	3,185
Other	4.6	102	479,900	22	104,326	4,704
Marine						
Seismic (P-wave)						
Compressed air	17.8	22,601	18,031,369	1,269	1,012,998	797
Gravity	1.0	1,118	16,200	1,118	16,200	14
Magnetic	1.0	1,118	16,200	1,118	16,200	14

*Total includes government and university activity.

GRAVITY AND MAGNETIC SURVEYS

Table 11 shows worldwide expenditures for gravity and magnetic surveys. The 1980 data show a 139 percent increase in the use of these tools. It should be noted that most of this increase was in the petroleum area, up 350 percent from 1979.

AIRBORNE SURVEYS

Statistical data on airborne surveys are shown in Tables 12, 13a, and 13b. Airborne activity increased 18 percent over 1979 with most of the increase coming in the petroleum area. Magnetic surveys are still the most popular airborne surveys. Just recently a new survey method, airborne gravity surveying, has been developed in this field. During the last several years considerable research and development has centered around the use of a LaCoste & Romberg gravity meter to acquire gravity data in a moving helicopter platform. During 1980, surveys were flown in the United States and Mexico totaling over 37,000 line-miles using this continuous "recording-while-moving" technique.

Table 17 shows worldwide average unit costs for all activities; but if one examines just the airborne cost/mile column, he will find two common price categories. The first of these, $40/mile or greater, probably represents the more sophisticated surveys utilizing high sensitivity equipment and perhaps special navigation systems. The second category is approximately $20/mile and probably represents survey costs for low-sensitivity equipment, reconnaissance programs, and government surveys.

LAND MINING

Expenditures for land mining activities are reported in Tables 14a and 14b. Mining activity in South America, the Far East, and Australia were up considerably over last year. The other areas either had about the same activity or declined slightly. We suspect that land mining activity in these areas is somewhat under-reported.

ENGINEERING, GROUNDWATER, GEOTHERMAL, OCEANOGRAPHY, AND RESEARCH

Two new tables (Tables 15 and 16), were added this year to report Engineering/Groundwater and Geothermal activity. Usage of land seismic methods, in terms of total line-miles, for both engineering and groundwater shows a drop from 1979 to 1980 although seismic usage shows the same dominance by refraction methods using dynamite. Offshore engineering seismic work maintained about the same level as in past years, domi-

Table. 8. U.S.A. petroleum seismic activity by area.

State	Acquisition costs (US $)	Line-miles	Crew-months* Company	Crew-months* Contract	Crew-months* Total months
Land					
Undesignated	87,086,800	10,979	12.0	178.0	190.0
Alaska	7,560,000	2,180	.0	37.0	37.0
Alabama	22,457,372	4,486	37.4	88.7	126.1
Arkansas	7,043,114	1,516	6.0	31.0	37.0
Arizona	8,555,275	1,478	13.0	21.5	34.5
California	29,988,263	7,415	47.0	110.1	157.1
Colorado	16,563,918	3,787	15.1	72.3	87.4
Florida	3,832,138	560	16.0	5.3	21.3
Georgia	1,556,428	443	2.0	7.0	9.0
Idaho	4,317,200	601	2.0	17.8	19.8
Illinois	668,000	110	.0	5.0	5.0
Indiana	560,000	83	.0	6.0	6.0
Kansas	12,190,450	3,825	7.8	67.7	75.5
Kentucky	3,370,000	703	5.0	17.8	22.8
Louisiana	101,436,944	20,258	71.5	582.5	654.0
Maryland	529,000	99	1.0	3.0	4.0
Michigan	21,690,649	5,515	22.0	123.0	145.0
Minnesota	958,845	189	.0	3.5	3.5
Missouri	695,385	293	.0	3.5	3.5
Mississippi	27,953,003	5,739	59.8	107.8	167.6
Montana	38,770,261	9,958	86.0	116.3	202.3
North Dakota	63,173,013	14,507	94.5	147.2	241.7
Nebraska	2,626,028	669	4.0	8.5	12.5
New Mexico	20,300,518	4,946	34.8	85.0	119.8
Nevada	9,562,188	1,741	10.9	36.3	47.2
New York	1,438,981	342	.0	10.8	10.8
Ohio	241,000	40	.0	2.6	2.6
Oklahoma	30,960,835	6,945	81.5	87.5	169.0
Oregon	3,150,000	450	.0	9.0	9.0
Pennsylvania	5,748,385	1,799	3.2	36.0	39.2
South Dakota	786,121	160	.0	2.2	2.2
Tennessee	5,347,159	1,475	4.5	25.8	30.3
Texas	225,270,193	51,253	434.5	1,003.6	1,438.1
Utah	39,845,924	5,526	44.9	113.0	157.9
Virginia	4,360,970	2,489	7.8	16.0	23.8
Vermont	265,771	69	.0	2.0	2.0
Washington	211,000	33	.0	1.5	1.5
West Virginia	3,442,314	1,324	12.5	11.3	23.8
Wyoming	58,626,274	10,103	68.3	205.3	273.6
Total Land	873,139,719	184,088	1,205.0	3,408.4	4,613.4
Marine					
Undesignated	17,851,840	11,320	.0	41.0	41.0
East Coast	6,090,400	13,513	6.0	14.0	20.0
Gulf Coast	81,567,360	138,018	68.2	161.5	229.7
West Coast	37,085,844	39,843	13.0	44.5	57.5
Total Marine	142,595,444	202,694	87.2	261.0	348.2
Total U.S.A.	1,015,735,163	386,782	1,292.2	3,669.4	4,961.6

*Total includes government and university activity.

nating acquisition costs in the engineering category. Geothermal activity is known to be under-reported, perhaps as much as 75 percent.

Oceanography activity has declined; but research was up over 71 percent. Further improvements will be made to the alternate questionnaire next year to encourage more reporting of data from these under-reported areas.

SUMMARY

In general, the data reported here are believed to be more complete than in 1979 due to better response to the questionnaires. Developments in the questionnaire format to encourage complete reporting are being investigated. As companies and contractors become convinced that the confidential and financially sensitive data requested on the questionnaires

Table 9. Petroleum seismic activity in Canada

Province	Acquisition costs (US $)	Line-miles	Crew-months Company	Crew-months Contract	Crew-months Total months
Land					
Undesignated	27,907,983	8,380	.0	126.0	126.0
Alberta	142,268,820	34,999	76.5	320.0	396.5
British Columbia	43,073,283	9,264	9.0	81.1	90.1
Manitoba	415,847	150	1.0	.8	1.8
Nova Scotia	350,000	112	.0	1.5	1.5
Northwest Territories	6,077,634	778	.0	7.8	7.8
Ontario	1,750,000	350	10.0	.0	10.0
Saskatchewan	8,217,610	4,016	2.0	30.8	32.8
Total Land	230,061,177	58,049	98.5	568.0	666.5
Marine					
Undesignated	25,260,000	23,138	2.5	21.0	23.5
East Coast	2,099,098	3,815	2.1	2.7	4.8
Total Marine	27,359,098	26,953	4.6	23.7	28.3
Total Canada	257,420,275	85,002	103.1	591.7	694.8

Table 10. Petroleum seismic activity in Mexico.

State	Acquisition costs (US $)	Line-miles	Crew-months Company	Crew-months Contract	Crew-months Total months
Land					
Various	28,850,000	6,415		95.0	95.0
Marine					
Various	14,679,000	32,335		30.0	30.0
Total Mexico	43,529,000	38,750		125.0	125.0

Table 11. Total worldwide expenditures on gravity and magnetic surveys in US $ (thousands).

Area	Petroleum	Minerals	Engineering	Geothermal	Groundwater	Oceanography	Research	Total
International						113	2,897	3,010
U.S.A.	22,893	2,334	324	452	177		310	26,490
Canada	770	4,045	3					4,818
Mexico	1,573	440						2,013
So. America	9,530	24					100	9,654
Europe	13,006	85	127				240	13,458
Africa	6,457	2,590			2,000		90	11,137
Middle East	4,682							4,682
Far East	10,076	302				240		10,618
Australia/ New Zealand	32	604	2					638
Total	69,019	10,424	456	452	2,177	353	3,637	86,518

are being properly safeguarded and protected, we believe that more complete data will become available.

ACKNOWLEDGMENTS

This report was made possible through the contributions of statistical data by companies, contractors, government agencies, and universities. For many of these organizations, compilation of these data was a long and tedious task. The Geophysical Activity Committee expresses sincere appreciation to all of these individuals who were instrumental in preparing and submitting their activity questionnaires. The committee welcomes comments and suggestions on ways to improve this report.

(Text continued on p. 1333)

Table 12. Total worldwide expenditures on airborne surveys in US $ (thousands).

Area	Petroleum	Minerals	Engineering	Geothermal	Groundwater	Oceanography	Research	Total
international								
U.S.A.	10,383	3,789	301	308	92		172	15,045
Canada	90	11,290					2	11,382
Mexico	1,573	440						2,013
So. America		100						100
Europe	727	1,131					200	2,058
Africa	2,069	7,083						9,152
Middle East	1,303	125						1,428
Far East	2,027	300				240		2,567
Australia/ New Zealand		3,110						3,110
Total	18,174	27,369	301	308	92	240	374	46,858

Table 13a. Western Hemisphere airborne activity in US $ (thousands).

Survey method	USA		Canada		Mexico		So. America	
	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost
Magnetic	338,615	8,672	240,545	3,465	75,500	2,013		
Electromagnetic	1,500	150	14,326	504				
Combined EM/Mag.			31,120	1,654				
VLF			400	10				
Input	40,285	1,871	120,985	4,842				
Radiometric (gamma ray)			42,423	906			4,500	100
R-S side-scan radar	295,270	4,380						
Total	675,670	15,073	449,799	11,382	75,500	2,013	4,500	100

Table 13b. Eastern Hemisphere airborne activity in US $ (thousands).

Survey method	Europe		Africa		Middle East		Far East		Australia	
	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost	Line-miles	Cost
Magnetic	49,845	927	185,235	3,578	44,000	1,303	105,531	1,584		
Electromagnetic	4,000	350								
Combined EM/Mag.	14,000	400								
Input	5,000	381	54,600	3,258					13,000	1,110
Radiometric (gamma ray)			34,411	1,511	6,500	125			105,000	2,000
R-S side-scan radar			36,700	805			15,000	983		
Total	72,845	2,058	310,946	9,153	50,500	1,428	120,531	2,567	118,000	3,110

Table 14a. Western Hemisphere land mining activity in US $ (thousands).

Survey method	U.S.A. Line-miles	U.S.A. Cost	Canada Line-miles	Canada Cost	Mexico Line-miles	Mexico Cost	So. America Line-miles	So. America Cost
Seismic dynamite			137	897				
Seismic vibratory	15	40						
Seismic other	94	324						
Seismic dynamite (refraction)	50	106	10	15				
Gravity	991	460	901	505				
Magnetic	1,647	181	827	109			200	24
Resistivity	258	84					145	192
Self-potential	940	128						
Electromagnetic	704	369	1,952	544			16	20
Combined EM/Mag.	910	250	1,354	429	11	2		
VLF	119	66	428	71				
Induced polarization	1,118	782	902	936				
Radiometric (gamma ray)			842	47			5,400	135
Radiometric (alpha track)			72	13				
Total	6,846	2,790	7,425	3,566	11	2	5,761	371

Table 14b. Eastern Hemisphere land mining activity in US $ (thousands).

Survey method	Europe Line-miles	Europe Cost	Africa Line-miles	Africa Cost	Middle East Line-miles	Middle East Cost	Far East Line-miles	Far East Cost	Australia Line-miles	Australia Cost
Seismic dynamite	1,114	10,401								
Seismic other	50	175					63	498	3	20
Seismic dynamite (refraction)			8	21					53	162
Gravity	35	10	908	895					23,090	601
Magnetic	20	75	1,163	175			12	2	20	2
Resistivity	1,155	346	224	43	1,045	313				
Electromagnetic	120	21	1,111	331					620	124
Combined EM/Mag.	209	53	500	123						
VLF	20	2								
Induced polarization	60	62	308	139			14	1	1,275	1,103
Radiometric (gamma ray)			10	1			1,100	5		
Other									750	600
Total	2,783	11,145	4,232	1,728	1,045	313	1,189	506	25,811	2,614

Table 15. Worldwide groundwater and engineering activity.

Survey method	Area Line-miles	Area stations	Footage	Time Crew-months	Time Man-months	Cost (US $)
Seismic reflection		100.0		1.0		12,000.0
Seismic reflection	27,060.0			61.5		9,724,874.0
Seismic refraction	4,262.0			172.2		3,226,915.0
Gravity	295.0			10.5		82,610.0
Magnetics		250.0			.7	5,000.0
Magnetics	25,715.0			38.7		2,546,300.0
Resistivity		1,516.0			39.4	235,600.0
Resistivity	42.3				3.3	28,500.0
Resistivity	3,536.0			81.4		2,214,900.0
Drill hole logging			42,815.0	10.7		142,500.0
Drill hole logging			361,324.0		91.0	746,875.0
Other	120.0			12.0		510,926.0
Total	61,030.3	1,866.0	404,139.0	388.0	134.4	19,477,000.0

Table 16. Worldwide geothermal activity.

Survey method	Line-miles	Area stations	Footage	Time Crew-months	Time Man-months	Cost (US $)
Seismic reflection	565.0			11.9		1,795,000.0
Seismic refraction	3.0			.5		15,000.0
Gravity		1,352.0		6.5		125,000.0
Gravity	110.0			3.5		20,000.0
Magnetics	24,200.0			4.5		308,000.0
Magnetotellurics		458.0		9.5		1,380,000.0
Magnetotellurics		110			9.0	117,963.0
Resistivity		14.0			.1	800.0
Resistivity	82.0			6.0		80,000.0
Drill hole logging			1,000.0		.3	800.0
Drill hole logging				9.0		1,300,000.0
Drill hole temp. grad.			36,350.0	15.5		603,000.0
Other	194.0			6.0		582,400.0
Total	25,154.0	1,934.0	37,350.0	72.9	9.4	6,327,963.0

Table 17. Worldwide average unit costs by survey objective, type, and method.

Survey objective, type and method	Crew months or (man months)*	Line-miles or (logged footage)	Acquisition costs US $	Average miles/month or (ft/month)	Average cost/month or (cost/man month)	Average cost/mile or (cost/foot)
Petroleum						
Land						
Seismic (P-wave)						
Dynamite	4,519.8	210,937	1,115,864,936	46	246,883	5,290
Compressed air	166.0	11,272	29,437,623	67	177,335	2,611
Electrical	1.0	625	250,000	625	250,000	400
Gas exploder	59.0	2,450	7,768,901	41	131,676	3,170
Weight drop	73.0	5,624	14,639,785	77	200,545	2,603
Solid chemical	49.3	1,576	10,041,200	31	203,675	6,371
Vibratory	2,382.6	141,502	555,580,944	59	233,182	3,926
Other	47.7	3,402	14,518,060	71	304,361	4,267
Seismic (S-wave)						
Dynamite	68.0	2,535	7,371,219	37	108,400	2,907
Weight drop	25.0	2,525	7,340,000	101	293,600	2,906
Vibratory	34.5	917	7,830,099	26	226,959	8,538
Seismic (refraction)						
Dynamite	99.0	5,588	23,752,000	56	239,919	4,250
Vibratory	76.0	2,648	12,030,000	34	158,289	4,543
Gravity	196.4	43,186	7,659,714	219	39,000	177
Magnetic	37.5	975	589,000	26	15,706	604
Resistivity	1.3	10	15,000	7	11,538	1,500
Electromagnetic	0.5	3	35,000	6	70,000	11,666
Combined EM/Mag.	20.0	200	85,000	10	4,250	425
Induced polarization	32.0	2,475	1,260,000	77	39,375	509
Magnetotelluric	35.0	405	4,280,000	12	122,285	10,568
Magnetotelluric	(15.0)	**	464,700	**	(30,980)	**
Other	8.0	250	1,200,000	31	150,000	4,800

*Total includes government and university activity. **Not applicable.

Table 17. Worldwide average unit costs by survey objective, type, and method. (cont.)

Survey objective, type and method	Crew months or (man months)*	Line-miles or (logged footage)	Acquisition costs US $	Average miles/month of (ft/month)	Average cost/month or (cost/man month)	Average cost/mile or (cost/foot)
Petroleum (cont.)						
Marine						
Seismic (P-wave)						
Compressed air	567.2	429,931	301,716,736	758	531,941	702
Electrical	7.7	6,938	2,593,000	901	336,753	373
Gas exploder	170.0	124,565	75,129,020	732	441,935	603
Implosive	248.4	60,460	17,537,025	243	70,599	290
Solid chemical	42.0	31,350	15,210,000	746	362,142	485
Other	1.0	30	100,000	30	100,000	3,333
Gravity	80.7	120,874	47,691,450	1,498	590,972	395
Magnetic	11.0	13,442	245,831	1,222	22,348	18
Airborne						
Magnetic	81.1	502,388	12,811,010	6,194	157,965	25
R-S side-scan radar	3.1	310,270	5,363,000	100,087	1,730,000	17
Drill hole						
Magnetic	3.0	(60,000)	22,000	(20,000)	7,333	(.37)
Resistivity	3.0	(60,000)	22,000	(20,000)	7,333	(.37)
Self-potential	12.0	(80,000)	480,000	(6,667)	40,000	(6.00)
Sonic/vel. logging	(49.6)	**	312,480	**	(6,300)	**
Induced polarization	3.0	(60,000)	22,000	(20,000)	7,333	(.37)
Minerals						
Land						
Seismic (P-wave)						
Dynamite	46.2	1,241	11,198,361	26	242,388	9,023
Dynamite	(12.0)	10	100,000	(1)	(8,333)	10,000
Vibratory	1.0	15	40,000	15	40,000	2,666
Other	41.9	210	1,018,115	5	24,298	4,848
Seismic (refracton)						
Dynamite	8.6	121	305,633	14	35,538	2,525
Gravity	(3.0)	395	3,000	(132)	(1,000)	10
Gravity	69.4	24,840	1,340,509	357	19,315	53
Gravity	30.2	**	1,106,700	**	36,646	**
Magnetic	45.5	2,638	435,601	57	9,573	164
Magnetic	(30.0)	1,251	135,495	(42)	(4,517)	108
Resistivity	63.5	2,737	953,900	43	15,022	348
Resistivity	(18.0)	90	27,000	(5)	(1,500)	300
Self-potential	6.8	952	128,600	140	18,911	135
Electromagnetic	68.5	4,509	1,150,376	65	16,793	255
Electromagnetic	(12.0)	**	277,435	**	(23,120)	**
Combined EM/Mag.	68.4	2,984	858,387	43	12,549	283
VLF	10.7	465	81,752	43	7,640	175
VLF	(30.0)	132	59,425	(5)	(1,981)	450
Induced polarization	174.5	3,149	2,725,275	18	15,617	865
Induced polarization	(10.0)	**	280,000	**	(28,000)	**
Radiometric (gamma ray)	17.3	7,352	189,724	424	10,966	25
Radiometric (alpha track)	0.6	72	13,950	120	23,250	193
Other	70.0	750	600,000	10	8,571	800
Airborne						
Magnetic	67.6	443,343	7,393,104	6,558	109,365	16
Electromagnetic	4.2	19,691	1,002,000	4,688	238,571	50
Combined EM/Mag.	18.1	45,120	2,054,500	2,492	113,508	45
VLF	.1	400	10,000	4,000	100,000	25
Input	46.6	233,870	11,462,300	5,019	245,972	49

*Total includes government and university activity. **Not applicable

Table 17. Worldwide average unit costs by survey objective, type, and method. (cont.)

Survey objective, type and method	Crew months or (man months)*	Line-miles or (logged footage)	Acquisition costs US $	Average miles/month or (ft/ month)	Average cost/month or (cost/ man month)	Average cost/mile or (cost/foot)
Minerals, Airborne (cont.)						
Radiometric (gamma ray)	49.8	192,834	4,642,576	3,872	93,224	24
R-S side-scan radar	1.0	36,700	805,200	36,700	805,200	21
Magnetic	1.0	(8,900)	10,600	(8,900)	10,600	(1.19)
Drill hole						
Resistivity	5.7	**	75,500	**	13,245	**
Resistivity	199.0	(1,600,000)	1,685,000	(8,040)	8,467	(1.05)
Induced polarization	5.5	**	69,440	**	12,625	**
Self-potential	3.0	(10,000)	10,000	(3,333)	3,333	(1.00)
Electromagnetic	(1.0)	(20,000)	18,000	(20,000)	(18,000)	(.90)
Radiometric (gamma ray)	12.0	**	100,598	**	8,383	**
Radiometric (gamma ray)	(26.5)	**	140,500	**	(5,302)	**
Radiometric (alpha track)	1.5	**	16,000	**	10,667	**
Radiometric (neutron activation)	43.0	0	1,178,987	C	27,418	0
Engineering						
Land						
Seismic (P-wave)						
Dynamite	2.0	10	8,000	5	4,000	800
Electrical	1.2	1,390	288,000	1,158	240,000	207
Implosive	0.5	90	120,000	180	240,000	1,333
Weight drop	1.0	15	10,000	15	10,000	666
Vibratory	1.5	20	75,000	13	50,000	3,750
Other	2.6	25	87,674	9	33,720	3,506
Seismic (refraction)						
Dynamite	25.3	252	1,267,415	9	50,095	4,984
Dynamite	(49.0)	85	525,000	(2)	(10,714)	6,176
Weight drop	21.0	259	180,800	12	8,610	698
Other	1.2	6	50,000	5	41,666	8,333
Gravity	6.5	280	82,000	43	12,615	293
Magnetic	4.5	270	67,500	60	15,000	250
Resistivity	32.8	1,027	602,300	31	18,362	585
Resistivity	(8.7)	42.3	53,500	(5)	(6,149)	1,265
Self-potential	3.0	20	12,500	6	4,166	625
Electromagnetic	9.3	33	38,000	3	4,086	1,151
Electromagnetic	(2.0)	100	25,000	(50)	(12,500)	250
Combined EM/Mag.	1.1	31	13,700	28	12,454	441
VLF	9.0	40	29,200	4	3,244	730
Input	3.0	80	10,000	26	3,333	125
Remote-snc thrm infra	1.0	20	20,000	20	20,000	1,000
R-S side-scan radar	1.0	20	20,000	20	20,000	1,000
Other	0.3	2	15,500	6	51,666	7,750
Marine						
Seismic (P-wave)						
Compressed air	14.8	13,080	3,620,200	883	244,608	276
Electrical	36.5	12,302	5,457,500	337	149,520	443
Gas exploder	1.1	108	56,000	98	50,909	518
Seismic (refraction)						
Electrical	56.0	1,374	515,000	24	9,196	374
Gas exploder	84.0	2,530	812,000	30	9,666	320
Airborne						
Magnetic	2.6	14,000	301,500	5,384	115,961	21

*Total includes government and university activity. **Not applicable.

Table 17. Worldwide average unit costs by survey objective, type, and method. (cont.)

Survey objective, type and method	Crew months or (man months)*	Line-miles or (logged footage)	Acquisition costs US $	Average miles/month or (ft/month)	Average cost/month or (cost/man month)	Average cost/mile or (cost/foot)
Engineering (cont.)						
Drill hole						
Resistivity	(1.0)	(12,500)	9,800	(12,500)	(9,800)	(.78)
Self-potential	2.0	(13,500)	15,800	(6,750)	7,900	(1.17)
Sonic/vel. logging	(56.3)	(74,389)	445,425	(1,321)	(7,912)	(5.98)
Electromagnetic	(.5)	(10,000)	9,000	(20,000)	(18,000)	(.90)
Radiometric (gamma ray)	4.0	(17,500)	11,300	(4,375)	2,825	(.65)
Radiometric (neutron activation)	1.0	(12,000)	25,000	(12,000)	25,000	(2.08)
Temperature gradient	1.5	(8,000)	8,500	(8,000)	5,666	(1.06)
Other	(7.4)	(30,897)	102,100	(4,175)	(13,797)	(3.30)
Geothermal						
Land						
Seismic (P-wave)						
Dynamite	5.0	299	883,000	59	176,600	2,953
Vibratory	5.9	248	802,000	42	135,932	3,233
Seismic (S-wave)						
Vibratory	1.0	18	110,000	18	110,000	6,111
Seismic (refraction)						
Dynamite	0.5	3	15,000	6	30,000	5,000
Passive monitoring	3.0	**	30,000	**	10,000	**
Gravity	9.4	130	144,000	14	15,319	1,108
Resistivity	6.0	82	80,000	13	13,333	975
Self-potential	(1.8)	70	10,900	(39)	(6,056)	156
Magnetotelluric	(53.0)	**	1,970,063	**	(37,171)	**
Other	4.5	210	71,000	47	15,778	338
Airborne						
Magnetic	4.5	24,200	308,000	5,377	68,444	12
Drill hole						
Temperature gradient	15.5	**	603,000	**	38,903	**
Other	9.0	**	1,300,000	**	144,444	**
Groundwater						
Land						
Seismic (P-wave)						
Dynamite	0.3	20	2,500	66	8,333	125
Seismic (refraction)						
Dynamite	(10.0)	50	200,000	(5)	(20,000)	4,000
Gravity	0.3	13	610	43	2,033	46
Magnetic	31.0	2,515	2,085,000	81	67,258	829
Resistivity	48.6	2,509	1,612,600	51	33,181	642
Resistivity	(33.0)	**	210,600	**	(6,382)	**
Airborne						
Magnetic	0.6	8,930	92,300	14,883	153,833	10
Drill hole						
Resistivity	(6.3)	(36,579)	16,900	(5,806)	(2,683)	(.46)
Self-potential	(3.1)	(25,984)	6,850	(8,382)	(2,210)	(.26)
Sonic/vel. logging	(2.5)	(7,575)	1,150	(3,030)	(460)	(.15)
Radiometric (gamma ray)	(12.9)	(123,240)	87,250	(9,553)	(6,764)	(.71)
Other	3.0	**	150,000	**	50,000	**

*Total includes government and university activity. **Not applicable.

Table 17. Worldwide average unit costs by survey objective, type, and method. (cont.)

Survey objective, type and method	Crew months or (man months)*	Line-miles or (logged footage)	Acquisition costs US $	Average miles/month or (ft/month)	Average cost/month or (cost/man month)	Average cost/mile or (cost/foot)
Oceanography						
Marine						
Seismic (P-wave)						
Electrical	4.4	13,150	1,125,000	2,988	255,681	85
Implosive	10.9	31,500	2,925,000	2,889	268,348	92
Other	6.6	24,746	1,136,530	3,749	172,201	45
Magnetic	0.9	7,100	113,000	7,888	125,555	15
Airborne						
Magnetic	2.0	20,000	240,000	10,000	120,000	12
Research						
Land						
Seismic (P-wave)						
Dynamite	8.2	601	1,796,000	73	219,024	2,988
Vibratory	19.0	969	2,555,745	51	134,512	2,637
Seismic (refraction)						
Dynamite	2.0	25	20,000	12	10,000	800
Weight drop	(1.3)	2	34,000	(2)	(26,154)	17,000
Solid chemical	1.8	49	6,130	27	3,405	125
Vibratory	(5.7)	**	379,500	**	(66,579)	**
Other	(1.0)	**	35,000	**	(35,000)	**
Gravity	28.6	2,843	265,000	99	9,266	93
Magnetic	3.0	100	23,000	33	7,667	230
Resistivity	21.0	870	39,000	41	1,857	44
Resistivity	(5.7)	**	84,200	**	(14,772)	**
Electromagnetic	3.0	4	8,000	1	2,666	2,000
Electromagnetic	(5.4)	**	109,800	**	(20,333)	**
Induced polarization	3.0	20	22,000	6	7,333	1,100
Radiometric (alpha track)	4.5	50	52,000	11	11,555	1,040
Marine						
Seismic (P-wave)						
Compressed air	13.5	39,846	1,062,500	2,951	78,703	26
Magnetic	20.3	98,516	2,977,500	4,853	146,675	30
Airborne						
Magnetic	6.3	26,410	372,475	4,192	59,123	14
Electromagnetic	0.1	135	2,000	1,350	20,000	14
Drill hole						
Sonic/vel. logging	5.0	**	275,400	**	55,080	**
Electromagnetic	(.5)	(1,000)	8,090	(2,000)	(16,000)	(8.00)
Combined EM/Mag.	(1.0)	(22,000)	5,000	(22,000)	(5,000)	(.23)
Radiometric (gamma ray)	1.8	(15,175)	37,450	(8,431)	20,805	(2.47)
Temperature gradient	0.5	(6,000)	20,000	(12,000)	40.000	(3.33)

*Total includes government and university activity. **Not applicable.

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